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PROGRESS REPORT

STUDIES OF THE EFFECT OF FEEDING, BIOLOGY, AND CONTROL OF THE ELM SPANWORM WITH DDT SPRAY APPLIED BY AIRPLANE

by

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INTRODUCTION

The elm spanworm. *Ennomos subsignarius* (Hbn.), is native to this country and ranges from the Atlantic westward as far as Colorado. Even though this insect is indigenous to the Southeast, it had never caused serious defoliation prior to 1954. Since 1954, when the present infestation commenced, the area defoliated has increased from a few small spots in Gilmer and Fannin Counties, Georgia, to over 550,000 acres in the States of Georgia, Tennessee, and North Carolina in 1958.

The defoliation to date has caused loss of growth, dieback of limbs and tops, and mortality of several hundred board-feet per acre on areas which have been defoliated for 3 or 4 years. In addition, intangible losses are occurring through destruction of the mast crops on which game and wildlife depend, depreciation of recreational facilities and activities, and shade tree defoliation. If the infestation continues without control, the economy of the area will be affected.

HISTORY OF PAST OUTBREAKS

At one time this pest was thought to occur primarily on linden and was named the snow-white linden moth. Subsequently it was found to be a pest of elm as well as of other species of hardwoods and given the accepted common name of elm spanworm.

The spanworm has occasionally increased in numbers locally and defoliated forested areas, particularly in the Middle Atlantic and Northeastern States. It has never been considered a serious forest pest anywhere in the United States until this outbreak occurred. Plumb and Friend (6) described an outbreak in Massachusetts which destroyed red maple by 2 or 3 years of successive defoliation in 1914-1918. Herrick (3) presents the injury, life history, and control of this pest on shade trees and states that the moth was abundant from 1860 to 1870 on eastern shade trees and from 1908 to 1910 in parts of the Catskills. Hamilton (2) noted that the spanworm in association with cankerworms so weakened trees that they were attacked by borers. Up to the present time the pest has generally been of nuisance value only.

THE PRESENT OUTBREAK

Area Involved

Detailed yearly reports of the area and degree of defoliation are contained in survey releases (4, 5, 7). Attacks have generally commenced and become more severe along the crests of the ridges and less severe toward lower elevations. Whereas general defoliation has not been as heavy at low elevations, selective feeding of larvae has resulted in some trees being completely defoliated each year in areas which otherwise would be classified as lightly defoliated. The occurrence of the infestation along the crests of the ridges is similar to cankerworm infestations which occurred in the southern Appalachians from 1952 to 1955. This fact is mentioned since there appears to be some correlation between conditions at these higher elevations and geometrid attack.

Hosts

The tree species most severely attacked by the spanworm in this outbreak were hickory and black walnut. These species have been completely stripped of their leaves each year. Defoliation of other species is variable from a trace to 100 percent; among these are all species of oaks, basswood, birch, maple, poplar, willow, black locust, dogwood, elm, beech, chestnut, ash, and apple. Tulip poplar and sassafras are not defoliated even though heavy egg deposition occurs on these species. Beneath heavily defoliated trees (fig. 1) nearly all vegetation, including rhododendron, is fed upon by larvae dropping from above. Apple trees were not a host until 1958 when feeding on orchards became common, and those lacking a spray program were completely defoliated.

PRELIMINARY STUDIES

Biology

Prior to determining the value of aerial sprays, the known biological data were checked against local conditions and found to be similar. The eggs are deposited in late June on the undersides of branches in irregular masses (fig. 2a). These eggs remain in a dormant condition until the following spring. In late April or early May the eggs hatch and the emerging larvae begin eating the expanding buds and leaves. The larvae which may be either green or brown in color increase in size rather rapidly as they feed until the latter part of May when the larvae attain a length of up to 2 inches (fig. 2b). Following the pupal period (fig. 2c) which lasts about a week, the moths appear (fig. 2d), deposit their eggs, and die--thus completing the annual cycle.

Fig. 1.--Hardwoods defoliated by the elm spanworm.

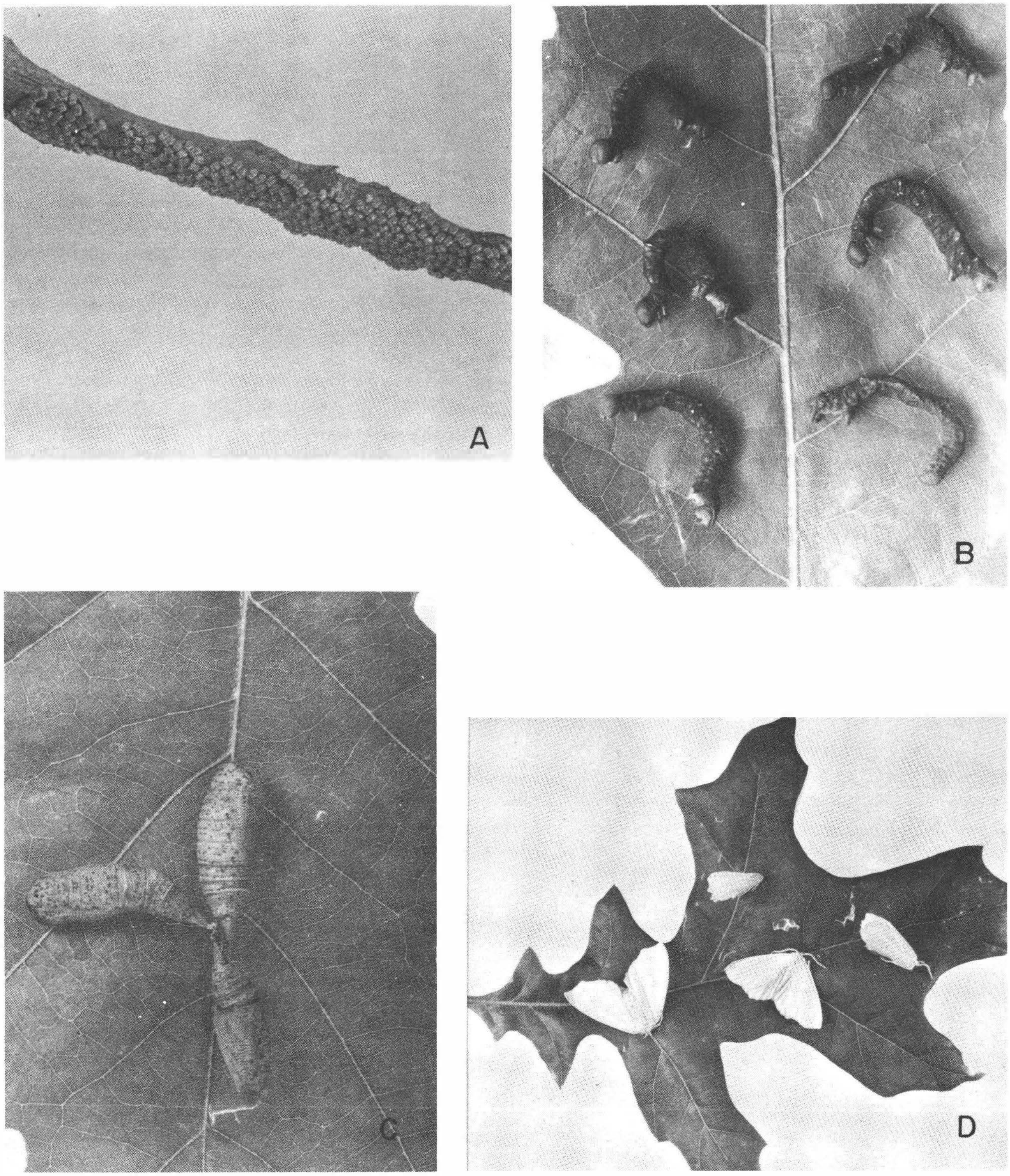

Fig. 2.--Stages of the elm spanworm.
A. Eggs C. Pupae
B. Larvae D. Adults

Biological Control

Natural control factors were sampled in 1956, and it was found that Hymenoptera, Diptera, and unknown causes were responsible for 4-, 32-, and 7-percent mortality respectively of late larvae and pupae. Pentatomids, spiders, ants, birds, and particularly carabid beetles were common predators. The following parasites were reared from late larval and pupal collections and sent to Mr. P. B. Dowden of the Northeastern Forest Insect Laboratory at New Haven, Conn., or to the Insect Identification and Parasite Introduction Section of the Agricultural Research Service for identification:

Diptera

Euphorocera floridensis
Chaetogaedia analis
Zenillia blanda
Phorocera sp.

Chalcididae

Brachymeria compsilurae
Brachymeria ovata

Ichneumonidae

Itoplectis conquisitor
Scambus pterophori

Whereas the Hymenoptera emerged during the same period as spanworm adults, June 28 to July 14, the Diptera did not commence emerging until July 14.

In 1958 during the latter part of April and early part of May the parasitic flies in the woods were extremely bothersome because of their persistence and numbers. In spite of the impression that one received of the large number of flies available, it was ascertained at the end of the season, by sampling larvae and pupae, that less than 30 percent were parasitized by Diptera.

Growth Studies

A study was carried out in July 1957 to determine the effect of defoliation on the increment growth of trees at various heights on the bole. Five hickories and seven oaks from 45 to 65 feet tall, ranging in age from 27 to 112 years and in diameter from 8 to 20 inches, were felled and sections taken from the bole. These sections were taken at stump, midbole, and base of the crown heights, and the growth during each of the previous five years was determined. This study showed that the effect of insect defoliation could be determined by measurements taken on the lower bole of the tree.

To determine the effect of defoliation on tree growth, 68 sampling stations were located at 1-mile intervals along roads on the Cohutta Ranger District. At each sampling station four trees were selected to assess the effect of the defoliation on growth increment. Whenever possible a white oak, red oak, hickory, and tulip poplar were selected for assessment of annual growth during the past ten years. The data in table 1 show that prior to 1955 the trees showed the same growth trend. During 1956 and 1957 when defoliation occurred, the growth sharply declined for the insect's favorite host species, hickory, red oak, and white oak, whereas the nondefoliated species, tulip poplar, did not show such a growth trend.

Table 1.--Effect of elm spanworm defoliation on the growth of hardwood trees in northern Georgia

Species	Sample	Average annual increment d.b.h.									
		1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
	Number trees	Inches									
Defoliated											
Hickory	45	.073	.070	.071	.069	.065	.062	.056	.065	.047	.033
White oak	58	.068	.068	.070	.064	.058	.055	.051	.052	.044	.035
Red oak	65	.110	.114	.107	.104	.091	.085	.086	.083	.071	.061
Not defoliated											
Tulip poplar	29	.253	.272	.260	.259	.209	.202	.186	.194	.196	.206

THE PILOT TEST

A pilot test was conducted to determine whether control of the spanworm by aircraft application is possible. The study was a joint effort of the Southeastern Forest Experiment Station, Region 8, and the Chattahoochee National Forest.

Responsibility for preparing the plan of work and technical phases of the study was under the leadership of the author. The selection and marking of plots and sample lines were delegated to Mr. Hoover Lambert. The spray was applied by the Jack Reynolds Flying Service of Candor, North Carolina, and East Palatka, Florida. His cooperation was very good as was that of several local pilots operating out of the Ducktown, Tennessee, airstrip. These pilots acting individually and as a group, together with

representatives of the Tennessee Copper Company, arranged for the grading of the airstrip, storage of gasoline and spray material, and loan of an airplane for observation prior to application of the spray. Ranger B. Davis of the Toccoa District provided radios for the operation as well as publicity of our objectives to the local population; additional publicity on the State level was provided by the National Forest and Regional office. This advance word of our objectives prepared the citizens so well that there were no adverse criticisms of the project.

Basis of Test

Research by entomologists has shown that other geometrids such as the cankerworms, with feeding habits and body structure similar to the elm spanworm, have been successfully controlled with aerial sprays of DDT. This fact lead to approval of the pilot test. On the basis of experience with defoliating insects, a decision was made to apply a single formulation of DDT at a specific dosage varying only the time of larval and vegetative development.

Objectives

The main objectives of the study were to determine:

1. If 1 pound of DDT in 1 gallon of kerosene per acre would provide effective control if applied by airplane.

2. The best timing of spray application with vegetative and insect development to provide maximum insect mortality along with maximum foliage protection.

3. If the insect could be controlled when the spray was applied simultaneously at all elevations.

Plot Selection and Marking

The Cohutta Ranger District constituted the study area. This district is in northeastern Georgia and contains a predominately hardwood forest type composed of oaks, hickory, maple, birch, tulip poplar, basswood, sourwood, sassafras, hemlock, as well as white, shortleaf, and Virginia pine. The principal species in the stands are the oaks. The district is at the southern end of the Appalachian chain and quite rugged in character varying from 1,000 to 4,500 feet in elevation. In general, the study area is typical of the forest type found throughout the mountains of North Carolina, Tennessee, and Georgia.

Due to the influence of elevation on vegetation and insect development the study plots were located at various altitudes. Two replicate and one check plot were located at each of the following heights: 1,700, 2,400, and 3,200 feet. Variation in elevation between 1,700 and 3,200 feet in the study area was related to a difference of about 14 days in plant and insect development in the spring.

The size of the plots was set at 50 acres each with the dimensions of 12.5 by 40 chains. Prior to selection of the plots, egg samples were taken to assure that suitable spanworm populations would be present for the tests.

Various methods of marking the corners of plots were tried and many others investigated. Helicopters, kites, balloons, aluminum tape, paint, smoke, and many others were all considered, evaluated, and abandoned. The corners were finally marked by fastening a large white sack filled with branches and leaves to a pole or several sections of a pole pruner and hoisting or fastening it into a "topped" tulip poplar tree so that the bag was extended about 15 feet above the forest canopy. Even though this method proved adequate for this study, it was felt that better methods of marking corners than are presently available should be developed.

Spray Formulation

Bids were solicited on the prepared insecticide since only 350 gallons were required. The Chapman Chemical Company was low bidder at 69 cents per gallon f. o. b. destination in 50 gallon drums. The formula used consisted of 1 pound of technical grade DDT to 1.25 quarts of auxiliary solvent and the balance kerosene. The bidder at his option substituted kerosene for No. 2 fuel oil.

The insecticide was loaded on a dump truck and pumped from the drums to the plane with a high-vacuum hand pump manufactured by the Tokheim Corporation, Fort Wayne, Indiana. We found these pumps to be light, easily changed from one barrel to another, and very efficient.

Timing of Spray Application

The larvae started hatching in the low plots on April 29. When reexamination of the area on May 7 determined that hatching had also commenced in the medium and high plots, the date of spraying was set for May 14. The variation in elevation caused the differences in insect and vegetation development shown in table 2.

Table 2.--Variation in elm spanworm and vegetation development at various altitudes in northern Georgia, May 14, 1958

Plot designation	Elevation	General foliage development	Insect development
	Feet		
Low	1,700	Full development	3d and 4th instar - 3/4 inch long
Medium	2,400	3 to 4 inches long	2d and 3d instar - 3/8 inch long
High	3,200	1/2 to 1 inch long	1st and 2d instar - 1/4 inch long

Spray Application

Due to the rugged terrain and location of the plots it was felt essential to locate a Stearman 450 for this study. The airplane secured was in good condition and equipped with a spray boom fitted with 32 Teejet hollow cone orifice No. D8, core No. 45 nozzles, arranged in pairs. Spraying was done at about 100 feet above the crown canopy at 85 m. p. h. with a pressure of approximately 50 p. s. i. According to our calibration of the plane the effective swath width was over 140 feet; however, during the actual spraying the swath width was considered to be 100 feet. Spray droplet size was in the medium atomization range of 175 to 225 microns mass median diameter. The plane was equipped to carry about 170 gallons of spray, but to increase the performance and safety factor, only enough spray was carried on each trip to treat two plots. The plane was operated from the Ducktown, Tennessee, airstrip which was about 10 miles and 1,000 to 2,500 feet below the spray plots.

The day prior to spraying the pilot was flown over the area and acquainted with the location and corners of the plots. Following this flight the pilot determined his order and manner of treatment. During each trip he would first treat a high, unobstructed plot and then a low plot. Since most of the low plots were adjacent to the mountains and more difficult to spray this provided a greater margin of safety since the plane performance was appreciably increased on these plots by the lighter load of both spray and gasoline. No markers were used on the plots except for the corners. The area was treated by parallel swaths applied at the discretion of the pilot.

Only one technical difficulty arose when spraying commenced. Due to the rugged terrain the pilot found that he had to use more power than he had anticipated. Since the spray pump pressure was regulated by the engine speed, the first spray load covered only 1-2/3 rather than 2 plots. Four nozzles were removed from each boom prior to spraying the remainder of the plots.

The Flat Top plot was sprayed at 6:30 a.m. followed by about 2/3 of the Dyar Gap plot. On the second trip Hemp Top and Sumac Creek were treated. On the final trip Grassy Mountain, Sawdust Creek, and the remainder of Dyar Gap were covered. Spraying operations were completed by 9:00 a.m. The weather was clear and cool and good for spraying with winds never above 5 m. p. h. during spray period. Several days of warm sunny weather followed the spray application.

Spray Deposit

Six oil sensitive spray cards, furnished by the Beltsville Forest Insect Laboratory, were placed around each sample tree to determine the amount and character of the spray deposit. It was possible to place these cards in openings at the high elevations, but development of foliage created almost a closed canopy on the medium and low plots. It can be seen by comparing tables 3 and 5 that there is little correlation between the amount of deposit and percent larval mortality in closed hardwood stands.

Sampling to Determine the Effectiveness of the Spray.

Sample lines were established along the diagonal of each plot and eight sample trees selected at about 5 chain intervals along this line. Whenever possible the trees were selected in openings to lessen the possibility of overlapping crowns and to enable securing a sample of the spray deposit on the check cards. Cloth trays to catch a calculable portion of the larval drop (fig. 3) were installed in a manner similar to that used for spruce budworm (1). By comparing the number of larvae dropping on a known area and determining the area of the crown of the tree, it was possible to convert the number of larvae collected on the tray to the number occurring on the entire crown of the tree. The number of larvae which survived was determined by felling each sample tree and examining it for larvae which were not killed by the spray. An effort was made to select various species of trees representative of the stand since populations were quite variable between species in the same area. Larval counts of mortality were made each day following spray application until counts in the spray plots were equal to or below those found in the check plots.

RESULTS

Larval Mortality

The first day following application of spray, larval mortality was very heavy. During the second and third day larval mortality was still heavy but dropped off rather rapidly. At the end of the seven days larval mortality was complete or had diminished to the point where mortality was no higher than in the check plots. The results of the spraying on mortality of the larvae are shown in tables 4 and 5. From these tables it can be seen that very good control was obtained on all of the spray plots with excellent control on the medium and high plots.

When one considers table 3 it might explain why less effective control occurred on the low plots. The deposit cards show that the hardwood foliage was so dense that the spray was filtered out before it reached the lower crown of the trees and thus larvae feeding on the lower leaves were not affected. In addition, the larger sized larvae on these plots required more DDT to control them.

On the high plots the larvae were small and easier to control. In addition, since foliar development was just initiating, the crowns were open and let the spray come down through and over the entire crown area. The early spraying thus protected more of this year's foliage since the larvae were killed prior to heavy feeding. In the low plots considerable feeding occurred before application of the spray.

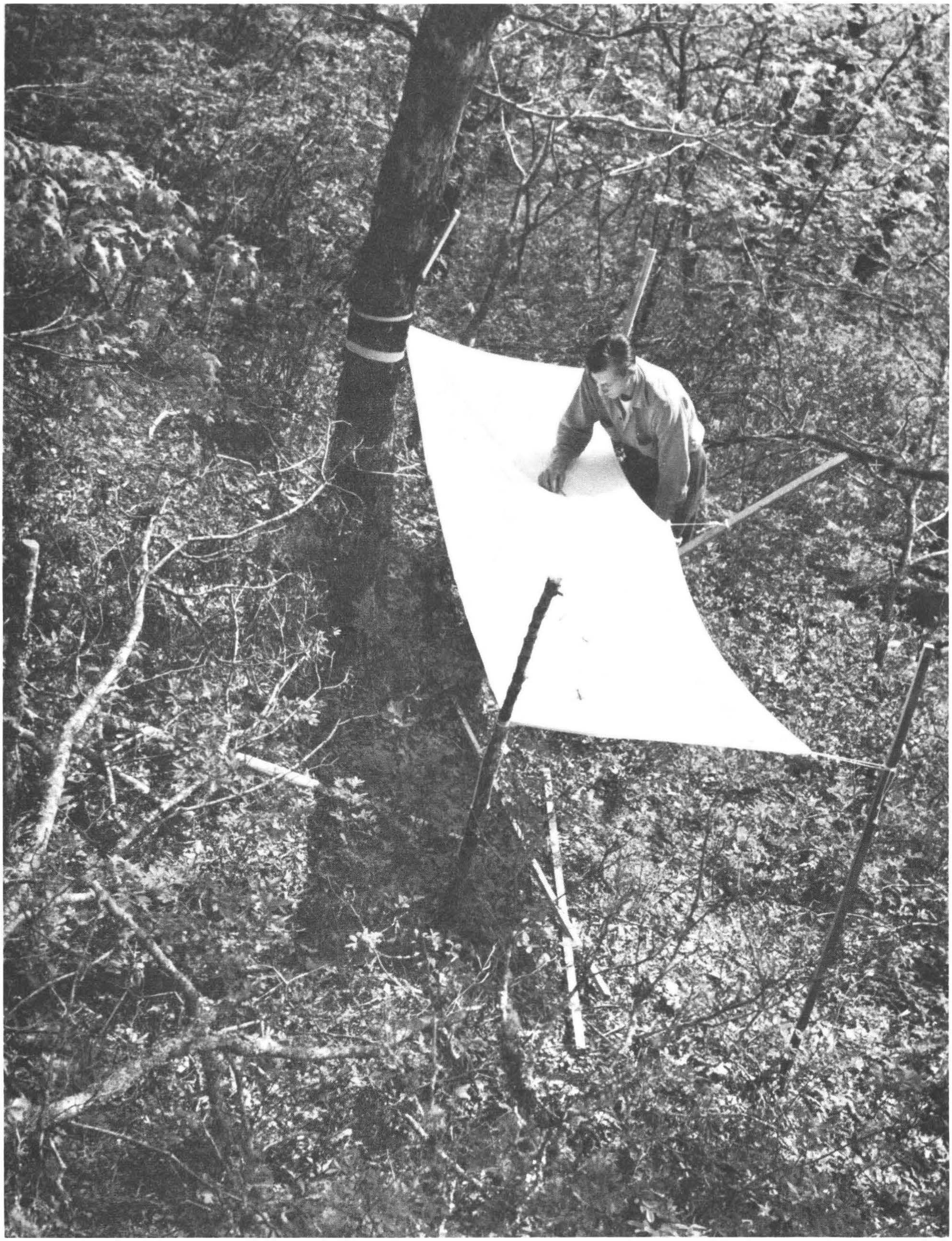

Fig. 3.--Cloth tray beneath crown to catch sample larval mortality population.

Table 3.--Average pounds per acre deposit of DDT per sample tree estimated by oil sensitive cards

Elevation	Sample tree number 1	2	3	4	5	6	7	8
	Pounds per acre deposit 1/							
LOW								
Sumac	T 2/	0	T	T	T	.1	0	0
Sawdust	T	T	0	T	T	.2	.1	T
Check	0	0	0	0	0	0	0	0
MEDIUM								
Hemp	.2	T	T	.2	.9	.5	.3	.1
Dyar	T	T	.1	T	.1	.1	T	T
Check	0	0	0	0	0	0	0	0
HIGH								
Flat	.4	.3	.2	.2	1.2	.4	.2	1.5
Grassy	T	.3	.2	.3	.1	.2	.3	.1
Check	0	0	0	0	0	0	0	0

1/ Sample of 6 cards per tree
2/ T = Trace

Table 4.--Survival of elm spanworm per sample tree following application of aerial spray in northern Georgia

Elevation	Sample tree number 1	2	3	4	5	6	7	8
	Number of larvae surviving spray							
LOW 1/								
Sumac	0	406	32	16	100	0	20	0
Sawdust	0	60	0 2/	0	30	0	0	0
Check	603	1850	120	2170	224	976	702	2100
MEDIUM								
Hemp	0	0	0	0	0	0	0	0
Dyar	0	5	10	0	0	0	0	0
Check	1073	1224	950	870	1000	900	1120	1209
HIGH								
Flat	0	0	0	0	10	0	0	0
Grassy	0	0	0	0	0	0	20	0
Check	2900	2410	3020	4518	5024	3110	4976	4562

1/ In low plot many larvae may have dropped on underbrush and not be included in sample since many were in pupal stage when these plots were sampled.
2/ A large number of pupae were observed on underbrush species below two defoliated hickories near this sample tree.

Table 5.--Percent control of elm spanworm by airplane application of DDT in northern Georgia

Elevation	Elm spanworm control by trees							
	1	2	3	4	5	6	7	8
				Percent control				
LOW								
Sumac	100	49	99	99	98	100	99	100
Sawdust	100	95	100	100	99	100	100	100
Check	73	15	47	7	94	37	6	6
MEDIUM								
Hemp	100	100	100	100	100	100	100	100
Dyar	100	99	99	100	100	100	100	100
Check	3	9	2	14	7	12	--	--
HIGH								
Flat	100	100	100	100	99	100	100	100
Grassy	100	100	100	100	100	100	99	100
Check	11	12	17	13	6	10	1	6

Number of Larvae Per Tree

There was a wide variation in the number of larvae per tree even when they were adjacent. Hickory nearly always had the largest populations. The check trees in table 4 show that populations per tree varied from 120 to over 5,000. Actually the range of actual populations on susceptible hosts was not as wide as this. The small figure in the low check plot was due to the advanced stage of the larvae when sprayed. By the time that the trees were felled for sampling, considerable natural mortality had taken place, and some larvae had dropped to the understory and pupated and are therefore not shown in the count totals.

Effect of Spray on Fish and Wildlife

Mr. Merkle from the Georgia Fish and Game Commission as well as Mr. Marvin Smith from the U. S. Fish and Wildlife Service checked small streams in the spray plots to determine the effect of the spray on bottom-feeding organisms. Because of the small amount of spray reaching the forest floor in the plots checked, the stream-bottom-feeding organisms were affected very little if any.

CONCLUSIONS

The excellent control attained by aerial application of DDT spray for elm spanworm control in the hardwood forests of northern Georgia is most gratifying since it is apparent that control operations may be required to prevent the serious damage now being done in the forest. This study demonstrated that:

1. Elm spanworm can be controlled by airplane spraying with 1 pound of DDT in 1 gallon of kerosene per acre.

2. The most effective control is obtained when the spray is applied when the larvae are small and foliage has expanded from 1/2 to 1 inch.

3. The larvae can be controlled effectively over a considerable period of time. Best control is obtained as in 2 above but, if necessary, spray can be applied simultaneously at all elevations after foliage has elongated, up to about one week prior to pupation.

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